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THE RELATIONS OF THE EARTH SCIENCES IN VIEW OF THEIR PROGRESS IN THE NINETEENTH CENTURY.[1]

FACTS of earth science have now been so abundantly acquired and so thoroughly systematized that there is some danger of our substituting the schemes in which earth-knowledge has been summarized for first-hand knowledge of the earth itself.

For a fundamental matter like the globular form of the earth we resort to a hand globe, so admirable in its imitation of nature that we must beware lest the little globe rather than the earth in its true dimensions satisfies our imagination. We have so conveniently divided the geological record of the earth's history into ages and periods that their easily repeated names are apt to replace the laborious conception of long divisions of time.

Our escape from the danger of taking scheme for fact has lain in the resort to individual observation, and the past century must long be famous for the extent to which advantage has been taken of the opportunity for outdoor study.

The earth has been explored and measured as never before. The lands have been mapped, the oceans have been charted by original observers. The air has been followed in its circuits, great and small. The structure of the earth's crust has been patiently traced out. Thus "Go and see" came to be our watchwords one hundred years ago. As long as we, like Antæus of old, can return to the earth for new stores of the strength that we find in facts, we need not fear being strangled by any voluminous Hercules of theory.

[1] An address delivered before the Department of Earth Sciences in the World's Congress of Science and Arts at St. Louis, September 20, 1904.

It is the active appeal to observation that has checked the freedom of speculation which our brilliant predecessors enjoyed in an earlier century, when their fanciful schemes were little restrained by the barriers of fact that have since then been built up on every side. Indeed, schemes came to be for a time so much in disrepute that some investigators wished to suppress theorizing altogether, as was seen in the effort to supplant the name "geology" by "geognosy." I rejoice that the effort did not succeed; for if earth science were really limited to facts of direct observation, it would be at best a dreary subject.

How uninspiring would be such a knowledge of tides as could be gained only by actual observation along the seashore! A collection of such records would be an orphanage, where the foundlings would doubtless be well cared for and thoroughly drilled in their little duties, and yet left without the inspiriting, enlarging influence of parental care that they find on adoption into the family of earth, moon, and sun.

Whatever the danger of schemes and theories, they give the best of life to our bodies of facts, and our science cannot survive without them. Indeed, we have come to know that the danger of systems and theories lies, not in their dependence on the imagination, but in the possibility of their careless growth and of their premature adoption, and even more in the acceptance of a personal responsibility for their maintenance, instead of leaving that responsibility to external evidence.

If there is any subject in which the aid of schemes and theories based on observations has been absolutely necessary for progress, it is earth science, where so many of the essential facts are invisible. It cannot be too carefully borne in mind that observation and theory are alike in their objects, however different they may be in their methods. Both seek to discover the facts of their science. One deals with facts that are visible to the outer eye; the other, with facts that cannot be seen, either because they are too small or too large for outer vision, or because they are hidden within the earth or in past time, or because they are impalpable abstractions or relations. In both, fancy is sometimes taken for fact, more often so perhaps in theorizing than in observing; but we must not for that reason give

up either means of investigation. We have learned that both observing and theorizing must be carefully conducted; and we have therefore replaced the earlier watchwords, "Go and see," with the later ones, "See and think." We may still give praise to those who apply themselves chiefly to gaining first-hand knowledge of observable facts, but we have learned to give greater praise to those who, on a good foundation of visible facts, employ a well-trained constructive imagination in building ingenious and successful theories which shall bring to sight the invisible facts. We have been longest familiar with the need of theory in those branches of our subject which have, by reason of association with mathematical problems, traditionally employed deductive methods in their discussion, as in earth-measurement; we are least familiar with it in those branches that have until lately followed for the most part inductive or even only empirical methods, as has so generally been the case with geography.

For example, in the study of the tides, already referred to, how unanimous we are as to the inadequacy of inductive methods; how universally we accept the marvelous theoretical scheme of interaction between planet and satellite, deduced from tidal theory; how we admire its extension to the supposed relation of the inferior planets to the sun! But in general geography, how little attention has been given to the deductive and systematic consideration of its many problems; how many geographers still look rather askance at those of their number who propose to treat geographical problems through theory as well as through observation! It seems to me clear that, while the earlier progress of geography was very largely inductive, the later progress has been largely determined by a free acceptance of deductive as well as of inductive methods, and that geography as well as geology is today profiting greatly from the use of our faculty of insight as well as of outsight.

The objections that are not infrequently urged against the employment of indirect, inferential, as well as of direct, observational, methods in certain branches of our science come from two sides. On one side is a misapprehension as to the nature of our tasks, a belief that our work may really be largely inductive, that observation alone will suffice, if patiently continued, to discover all pertinent facts. This is a serious mistake; there is everywhere more unseen than seen.

On the other side is the fear that theories may become our masters, and that we may appeal to them as infallible, and thus set ourselves up as authorities. This is a most natural induction from the history of our earlier progress, for we have repeatedly seen the sincere young investigator grow into the impatient old autocrat; it is a bit of human nature that we share with the rest of the world; it is analogous to the change of meaning in the word "tyrant," from a mere king to an arbitrary despot. But there is another verbal analogy in the change of the word "skeptic" from inquirer to doubter, and it is this analogy that we are now following. We have learned to doubt because we know we may be deceived; we mistrust careless eyes as well as careless thoughts, and insist that careful scrutiny be given to the work of both; we reduce the dangers of theorizing just as we reduce the errors of observing, not by avoiding that indispensable means of investigation, but by practicing it carefully, until we become experts in thinking as well as in seeing; and all this constitutes an important element in our recent progress.

In spite of what has already been gained by good theorizing, few realize how largely earth science, apparently a matter of observation, is really built up of inferences that go far beyond mere inductions. Many of the inferences have gained a certification so good and so familiar that in respect to verity they take rank with seen things, and we are apt to forget their origin. The successive deposition of bedded rocks, the organic origin of fossils, the original horizontality and continuity of folded and eroded strata—these inferences are today accepted as if they had never been doubted; but they all were once doubted, and they had to make their way against opposition. Whatever order of certainty they have now acquired, they are not facts of observation, but facts of inference; and, like the great body of earth science, these now well-accepted facts of past time have not been determined by direct seeing, but by inference on the basis of seeing. We may therefore justly claim great progress for earth science, not only in the extent and accuracy of our observations, but also in the extent and accuracy of our inferences. While there is yet need of more conscious recognition and more thorough training, especially in the deductive processes by which many problems may be solved, we may still say that among the most significant steps we

have taken in the past century are those by which the necessity and the value of theorizing have gained frank acceptance among investigators, and by which many of the results of theorizing have gained an order of verity that compares well with that of facts of mere observation.

An illustration of this phase of our progress is to be found in two definitions, each of which has a certain currency. By some writers, geology is defined as the study of the earth's crust, thus emphasizing the observational side of the subject; by others, geology is defined as the study of the earth's history, thus giving fuller recognition to the growth of inference upon observation. The second definition does not lessen the essential importance of observation as the foundation of knowledge, but it accords a proper value to inferences, and in this way is characteristic of what seems to me sound scientific progress. The earth's crust contains the incomplete, partly concealed, partly undecipherable records on which we are to construct the science of geology; just as human monuments and writings are the records on which we are to construct human history; but in neither case are the records and the history identical, for the history in both cases includes a great body of inferences as well as of more directly recorded or observed facts.

The wholesome appeal to observation in the search for visible facts has loosened the control of supposed authority and has given us much of the freedom necessary for progress; but the assistance of the trained imagination in the search for invisible facts has in a far greater degree corrected the assumptions of an earlier stage of inquiry; it has even revised the dicta of philosophy and remodeled the dogmas of religion.

The inferential element of our progress has worked most beneficently. It is largely through our inferences that we have come to recognize the interdependence of the different parts of earth science. The climatologist may remain as provincial as he wishes; or he may enter through the gateway of present conditions the vast domain of past time, and on the way make friends with all the world; for he will then join hands with the petrographer, who has evidence of ancient desert conditions in the form of the grains in certain sandstones; and with the paleontologist, who infers the existence of ancient ocean

currents from the drift of graptolite stems; and with the glaciologist, who is asking the astronomer and the physicist whether one or the other of them can best account for the Pleistocene ice-sheets.

Not only do the different parts of earth science thus connect with one another, but, as the last illustration showed, they interlace most interestingly with the branches of other sciences in the forest of knowledge. The systematist would, indeed, be at a loss to classify our work, if in classification he thought to keep it apart from other kinds of work. Better let it grow up naturally with interlacing tree-tops and crowded underbrush, each tree showing its individualized effort in the universal competition, than seek to trim it into an orchard of separate trees. The departments and sections into which we are divided in this congress do not represent objectively disconnected groups and units of knowledge, but associated parts in contiguous growths of acquisition; we must not hesitate to go out of conventional bounds and to trespass, as it is called, on other departments, when it is to our advantage. Others are surely free to do the same by us. When we employ methods called mathematical and physical in our study of the winds, the profit is not only found in direct results, but also in the use of deduction and experimentation, so familiar in mathematics and physics, and so much less practiced, yet so much needed in all parts of earth science; in return we supply data for the study of the phenomena of gases on the largest terrestrial scale.

We must be chemists, geometricians, and physicists in studying the minerals of the earth's crust; and in return we supply to the chemist a great variety of natural compounds, and to the physicist the material basis for a remarkable variety of optical phenomena. We must indeed marvel at the skill displayed by minerals—which invade, colonize, migrate, and settle again in the dark inner world—in handling external rays of light, and we may wonder if they have not had some preliminary practice on radiations of a kind that physicists have yet to describe. Admirable also are the crystalline forms that give realization to the early inventions of geometers, much in the way that planets and comets give us in their orbits great natural examples of the conic sections, familiar for centuries as mathematical abstractions.

But it is particularly with biology in all its branches that we have

learned to borrow and lend. The evolution of the earth and the evolution of organic forms are doctrines that have reinforced each other; the full meaning of both is gained only when one is seen to furnish the inorganic environment, and the other to exemplify the organic response. Without question, the interaction here discovered in the working of two great processes is the most notable discovery of the past century, not the less glorious because we share it with other sciences. For if they have to do with the players, we have to do with the scenery and the properties for the all-world stage, where the success of the players has been conditioned by our setting since the play began. In the universal habit of respiration as a means of gaining the energy by which all plants and animals do their life-work, we see a successful response to the presence of free oxygen, mixed in the air or dissolved in the waters, and hence we infer that free oxygen has been present in atmosphere and oceans, at least as long as life has existed on the earth. In the development of stem and root, of dorsal and ventral parts, we perceive the everlasting persistence of gravity; to fail in the recognition of this elementary example of interaction between life and environment would be on a par with neglect of the earth's rotation because the evidence of it is found in the commonplace consequences of sunrise and sunset.

The races of mankind, so inappropriately treated as a chapter of physical geography in many of our text-books, but really the prime factor of political geography, are obviously determined by the larger features of the lands; just as the development of the higher organic forms has been determined not on the monotonous ocean floors but on the lands, where variety has really been the very spice of life.

If we turn to history—not simply to the politics of the past, but to the real history of human thought and action—the progress of our own science furnishes innumerable examples of response to environing opportunity: how natural that the later geological series should have been first deciphered in England, where it is so well displayed; that the study of earthquakes and the invention of seismographs thrive in Italy and Japan; and that geomorphy advanced rapidly in our arid West through the study of the nude, just as sculpture flourished in Greece.

It is but the commonplace of economics to show the large depend-

ence of modern civilization on the occurrence of mineral deposits. Like the quiescent crystalline forces in the rounded quartz grains of ancient sandstones, still capable of determining the settlement of new molecules around the old ones, the marvelous stores of dormant energy and strength in beds of coal and iron ore have long bided their time. After ages of neglect, they have become the centers of great populations; and now that our princes of industry have through countless difficulties touched and awakened them to life, we find a new meaning in the old fairy story of the Sleeping Beauty.

Even those broader considerations that we meet in philosophy and religion have developed new phases as the schemes of earlier times have been modified in view of the geological record: the place of work in the world, not a curse, but a duty; the date of the golden age, not behind us, but ahead; the view of death, not a punishment, but a natural element in the progress of life; even the conception of immortality has come to be—with some—directed less to speculations about a continued life elsewhere than to the study of the continuity of life here.

Religious ideas themselves—at least when we examine them objectively in the beliefs of others than our own people—are seen as if in a mirror held to nature; and the very gods of the lower religions are but reflections of the powers of earth.

It is only when we consider these broad phases of earth science that we gain our share of profit from the revolution that replaces the teleological philosophy of the first half of the nineteenth century by the evolutionary philosophy of the latter half. Our conception of the earth as well as of its inhabitants has been profoundly modified by this revolution, and much of our progress has been conditioned on the full acceptance of the newer view.

Now, if apology is needed for introducing the preceding considerations, which some might call irrelevant, let me urge that whatever share they may make of other sciences, they are also so closely grafted into one or another branch of earth science that we, as geologists or geographers, cannot afford to neglect them. In so far as they are related to elements of our science as consequences are to causes, as responses are to environment, we must take at least some account of them, even if their study in other relations is left to specialists in

other subjects. In doing so, we are only carrying out our work to its legitimate conclusion. It is without question our responsibility to study the ancient inorganic conditions that determined the location and the migration, the development and the extinction of ancient faunas, for these conditions were at least in part geological factors of one kind or another; it is equally our responsibility to study the modern conditions that determine the location of cities and the routes of trade, for these conditions are largely geographical factors; but the examples of organic response here adduced are merely a few of many, and all the rest stand on an equal footing with them, whether they are commonly classed with biology or history, with economics or religion. We long ago saw that the more simple, immediate, and manifest examples of organic, especially of human, responses belonged in the realm of geography; and from this beginning we now realize that there is no stopping-place till we include all other examples, complex, indirect, or obscure as some of them may be; for there is a graded series of connecting examples from the most artful human response down to the most unconscious plant response, and from the immediate responses of today back to the earliest responses of the geological ages.

It would be most arbitrary to draw a division in our studies, when no division exists in the things studied. It is therefore a piece of good fortune that geographers are coming to follow the practice of geologists, and thus to accept among their responsibilities the great breadth of physiographic and ontographic relationships existing today, as geologists have accepted them for the past. And it is also as good fortune that biologists are coming to accept the responsibility of studying environment as well as response; for only in this way have the earth and its inhabitants really learned to know each other. I rejoice therefore whenever a student of earth science completes his studies by carrying them forward to their organic consequences, as seen from the side of the earth; and again, whenever a student of biology, of language, of economics, of religion, carries his studies backward to a consideration of inorganic causes, as seen from the side of life; for thus and thus only we may hope that the knowledge of both causes and consequences shall increase in fulness. Our present understanding of this interdependence, not only of different branches

of our own science, but of the branches of our own and of other sciences, is truly a great step toward the solution of the wonderful riddle of the world.

The real foundation of the broad consideration of earth science rests on the continuity of ordinary processes through the long periods of recorded earth-history. Nothing has so profoundly modified the appreciation of other subjects as well as of our own, as the teaching of geology concerning the conception of time and the long procession of orderly events that has marched through it. Such a conquest of the understanding is enough to make us proud indeed; yet when we realize how short a share of time has been allotted to us, how sincere should be our humility! Today we may be lords of creation, powerful through cephalization; yet in face of the repeated extinction of dominant races in geological history, how can we think otherwise than that we are clad only in a little brief authority; how can we seriously believe that we represent the highest stage, the acme of organic development, comforting and flattering as this deductive opinion may be!

The conception of the continuity of processes, without extra-natural interference, has been forced to fight its way against opposition; now it has gained at least a very general verbal acceptance among us, and is quietly drifting into popular belief. To realize its full meaning is an arduous task, not only because of the opposition of inherited prejudices, but even more because of the inherent difficulty of the problem. To think that processes such as those of today have done all the work of the past is appalling; yet we are constrained to believe it. Even as waves, beaten up in a stormy sea, subside after the winds are calmed, so the mountain waves or wrinkles of the earth's crust, growing as long as orogenic storms are at work, are in time calmed to plains; and this not by unusual processes, but by the patient weathering and washing of scraps and grains. While these slow changes go on in the extinction of mountain systems, the races of plants and animals that originally gained possession of the lofty young mountains, that grew up with them so to speak, must either adjust themselves to the changes in their surroundings, or migrate to other homes, or vanish, all in due order through the flowing current of time.

Nowhere is the orderliness of geological changes better attested than in the forms of ridge and valley seen today in various examples, young and old, of wasting mountain ranges themselves, and in the systematic adjustment that is attained by the drainage lines with respect to the structures on which they work. Here, indeed, is cumulative testimony for uniformitarianism; for nothing but the long persistence of ordinary processes can account for these marvelous commonplaces. So wonderful is the organization of these land and water forms in physiographic maturity and old age, so perfect is their systematic interdependence, that one must grudge the monopoly of the term "organism" for plants and animals, to the exclusion of well-organized forms of land and water. By good fortune, "evolution" is a term of broader meaning; we may share its use with the biologists; and we are glad to replace the violent revolutions of our predecessors with the quiet processes that evolution suggests.

It is the assurance of orderly continuity that binds the past to the present in the endless sequence of events, and shows us that geography is only today's issue of a perpetual journal, whose complete files constitute geology. He must be a geographer of the old school who would now maintain that his subject, in content and treatment, really belongs outside of the geological curriculum. It may, on the other hand, be justly contended that the whole of earth science is made up of geographic sheets—until today, paleogeographic, if you like—all horizontally stratified with respect to the vertical time line. In every sheet we find news of the relation of carth and life, of environing control and organic response, of physiography and ontography. Every little item of news here published is worthy of close attention. The reader may examine all sorts of items on a single sheet and consider their temporary, areal distribution, and so acquire the geographic view; or he may examine the changing items of certain areas, following their chronological sequence in successive sheets, and so acquire the geological view; but it would be unfortunate if, in so doing, he did not perceive the interchangeable relations of these two methods of investigation.

There is, to my understanding, a great profit that has been gained from conceiving the whole body of our science in the way thus suggested. Branches such as meteorology and terrestrial magnetism,

which we ordinarily treat as parts of physical geography and thus associate with present time, are seen really to have their ancient as well as their modern, their geologic as well as their geographic, phases. We can gain some hints as to ancient meteorology, for we find records of paleozoic raindrops, of remote glacial deposits, and we hope yet to find evidence concerning the distribution of early climatic zones. As far as ancient records of this kind can be pieced together, we may study them in their momentary or geographic, as well as in their continuous or geologic, relations. Concerning ancient phases of terrestrial magnetism we are at a loss; yet our conception of even this branch of earth science, as well as that of the meteorological branch, is certainly broadened when it is regarded as a contemporary of all the geological ages, and not merely as a latter-day characteristic of the globe.

Similarly, those geological events which we are accustomed to treat in their time sequence, gain fuller meaning when they are decomposed into their momentary elements, and when each element is treated as a geographical feature associated with its contemporary fellows. The columnar sections of stratified rocks, for example, so useful in the understanding of historical geology, are like the edgewise view of a closed book. The book must be opened, the leaves must be turned over one by one, the pages of these early records must be read, like so many gazetteers of ancient times. Never mind if some pages are worn and others are missing; those that can be still deciphered assure us that the past was generally like the present, and warrant the generalization that geology is like nothing so much as a whole series of geographies.

At the present stage of our progress, the sciences of the earth may be given a somewhat different classification from that of the eight sections into which they are divided for the purposes of this congress. These sections, as it seems to me, represent the subjective divisions of our sciences, within each of which specialists may limit their studies more or less closely, and for each of which speakers may be provided. But when regarded objectively, the divisions, their grouping, and their relative values, must be otherwise presented. Geology objectively considered is not merely one of the earth's sciences; it is the whole of them: it is the universal history of the earth.

It is true that geology has so largely to do with past time that it is not popularly understood to include the present; but it certainly does include the present, and the future also, as fast as it arrives. There is no possibility, in the understanding that we have now gained of earth science, of stopping the geological record at any stage of the Pleistocene, and calling the rest "geography;" that would involve the resurrection of buried theories, which held the past to be unlike the present order of things.

Conversely, geography is stultified when absolutely limited to the things of today, as if the things of the past were of another nature. It is of course popularly so considered, and perhaps for that reason its scientific development is stunted. When regarded objectively, the geography of today is nothing more nor less than a thin section at the top of geology, cut across the grain of time; and all the other thin sections are so much more like the geography of today than they are like anything else, that to call them by another name—except perhaps "paleogeography"—would be adding confusion to the earth's past history instead of bringing order out of it. Our plain duty here is to emphasize the continuity of events, that great result of our studies, and not to imply a break in their succession by using unlike terms for different members of a single series.

Geology thus being composed of a succession of countless geographies, geography, in its widest sense, is likewise composite, including its inorganic and its organic parts. It is particularly concerned with the surface of the earth today, as the home of life; but "surface" and "today" must here be very freely construed; for we must draw upon the sub- and super-surface parts, and on the days before today, whenever we find profit in so doing. When we study the shape and size of the earth, we touch upon what may be developed into geodesy. When we study the inorganic parts of the earth for themselves, in what may be called their static relations, we enter upon mineralogy and petrology, or geochemistry; for it must be remembered that water is a mineral and that air is a rock. When we study the dynamic relations of the inorganic parts of the earth, we have geophysics, within which oceanography and meteorology are subdivisions, of rank similar to terrestrial magnetism and to that large category of phenomena that includes the activities of the earth's crust. It is true

that physical or dynamical geology is the heading under which erosion, volcanoes, and earthquakes are usually treated, as if the present phenomena of the earth's crustal envelope were to be set aside from the present phenomena of the hydrosphere and atmosphere, and associated chiefly with the history of the past. But we have now certainly reached a point when the unity of all these subjects, their interaction in space, and their continuity through time demand their association in a single group of studies which shall embrace all the activities of the earth in their present manifestation; with the full understanding that the present is only the latest addition to the past, and that the past is only the integration of a vast series of ancient presents.

All these present physical activities, even if carried down to such specialties as potamology and kumatology, are so closely associated with the standard subjects of geography that it is difficult and unadvisable to cut them asunder. Yet every one of them may be carried to such a degree of detail as to stand apart, and gain rank as an independent study. The accuracy of the geodesist, the minuteness of the mineralogist, the high flights of the meteorologist have now gone so far in their special development as to lead far away from each other, when they are studied for themselves, however closely their more general results may be associated.

When, however, we study the inorganic features of the earth, not as independent phenomena, but as elements of organic environment, they all belong strictly in physical geography, or physiography. Parenthetically, let me say that I regret the excessive breadth given to this term by British students, and the narrowness imposed upon it by those Americans who would limit it to the study of the lands. When we pursue the subdivisions of physiography, nomenclature becomes incomplete: climatology is unique in being a name for the study of the atmosphere in so far as it determines organic environment; economic geology is a study of useful minerals and rocks, but is less strictly treated as an objective subdivision of physiography than is climatology; and there is associated with it so much of ingenious artifice in the exploitation and treatment of mineral products that we are apt to put the cart before the horse and think that we make gold or coal serve our needs, instead of realizing that we make ingenious

use in money and fuel of the properties that gold and coal possess, just as we make use of moving air in wind-mills and of falling water in factories.

There are no special names for the phenomena of oceans or of the other divisions of physiography, considered as elements of organic environment; and there is perhaps no need of such names. Yet I hold that it is desirable, and even important, to recognize the two ways in which the inorganic features of the earth may be studied: either for themselves, without regard to their controls over organic life; or as elements of an inhabited planet, with continuous attention to the controls that they exert over the inhabitants.

When we come to the organic inhabitants of the earth, it is evident that they fall under biology when studied for themselves, and that they may be divided under botany and zoölogy, and subdivided as often as is desired. This is manifestly true as well of fossils as of living forms. When, on the other hand, the inhabitants of the earth are studied with respect to the responses that they have made to their inorganic or physiographic environment, they are appropriately included under geography. It has been recognized for many years that no geographical description of a region is complete without some account of its plants and animals, and especially of its peoples; just as no paleogeographic account of a geological horizon would be satisfying if its fossil fauna and flora were left unmentioned. But in recent years it has been seen necessary to treat uniformly all the organic elements of geographical descriptions in their relations to environing controls; for, as I have already shown, if a beginning is made, there is no reasonable stopping-place until this end is reached.

We are in this matter still sometimes too much under the control of traditional methods of treatment; we do not fully enough put into practical effect the greater lessons that we have learned. The earth as the home of man is a primitive, elementary definition of geography; the earth as the home of life is more consistent with present progress. Earth science has now certainly reached a position in which the unity and continuity of life are recognized. Let us then adopt this position as our starting-point in the organic half of geography that may be called ontography. Let us make it practically useful by treating all organic responses to environment under one general heading,

even though we afterward find it desirable to treat human responses in a separate chapter. For even if man's will sets him high above the other forms of life, it must not be forgotten that his will often leads him along physiographic lines, and that he possesses many structures and habits entirely independent of his will, and similar to the structures and habits of lower animals as examples of ontographic responses. Even human houses and roads are only different in degree from the houses and roads made by animals of many kinds. Still more, if we accept the principle of the continuity of geography through geology, we must recognize that most of the successive geographies of the past have had nothing to do with the human will, and that man and his works are after all only modern innovations.

The chief impediment to action upon this view, which, as I have said, has been unfolded before us by the progress that our science has already made, is the habit of studying geography and geology too separately, and of regarding the former as a subject for narrative treatment, while the latter is admittedly a subject for scientific investigation. The hint to this effect that is given by the unlike constitution of geographical and geological societies the world over ought not to pass unnoticed. Membership in many geological societies is limited to experts; if membership in a single geographical society is similarly restricted, I have yet to learn of it.

Let us then build on the progress we have made; let us realize that only when ontography is treated as thoroughly as physiography will geographical work gain the best geographical flavor. So empirical has been the traditional geographical treatment of the organic elements, so imperfectly have the organic elements been generally recognized as balancing the inorganic elements in the make-up of the subject as a whole, that no name has come into use for the organic half of geography corresponding to physiography for the inorganic half; and it is to supply this lack that I have elsewhere suggested the name above used. I believe that the adoption of some such name would aid in the systematic cultivation and in the symmetrical development of geography, and thus of geology also as a whole, by bringing more prominently forward the necessity of giving—or at least attempting to give—as scientific a treatment to the inhabitants of a region in their geographic relations as to the region itself.

The adoption of some such term as "ontography" would tend to correct the false idea that geography is concerned only with the elementary and manifest examples of organic responses; it would promote thoroughness of study, and thus more fully continue the progress that we have thus far made. The adoption of the term would, moreover, emphasize the principle of continuity through time—of the geographical stratification of geology, which is of so great importance in the scientific development of our subject; for ontography, in which persistent physiographic influences make themselves felt through inheritance, is then seen to be only the modern member of a great series with whose earlier members we have long been familiar in paleontology. The recognition of the continuity, the essential unity of these two subjects—one dealing with the living forms of today, the other with the dead forms of the past—dignifies the first and vivifies the second; and adds yet another argument in favor of an objective rather than a subjective classification of the sciences of the earth. The beginning of the cultivation of ontography, already made more or less consciously, strongly suggests a larger development for the future. We are thus assured that as the details of organic responses are worked out and the importance of physiographic details is recognized, the difference between physiography as the study of environment, and geochemistry and geophysics as the study of the earth for itself, will diminish. Today no one can say how far the details of these semi-independent sciences may not be found essential in physiography.

Let me now amuse you for a moment with a scheme of terminology that might have a little value if some of its terms were not already appropriated in other meanings. The scheme does not represent the historical development of earth science, but sets forth its several parts in the relations that our progress up to date shows them to stand.

Suppose we should use the ending *-ology* to denote the conception of sequence in time, and *-ography* to denote the conception of temporary distribution. We should then have our whole subject, geology, in which time sequence is the dominant idea, made up, like an endless prism of mica, of an indefinite number of momentary sheets of geography that cleave across the time axis. Biography would then lose its

limitation to man, and become the study of temporary floras and faunas in successive geographies; while biology would give up its usual meaning and become the study of life in the developmental sequence of organic evolution through geological time. The study of the minerals and rocks of any epoch would be minerography and petrography, while mineralogy and petrology would treat problems of paragenesis and metamorphism in which the passage of time is essential; and for one, I should then be able to remember what petrography and petrology mean. So we might go on with physiology, meteorology, and oceanology as made up of a succession of physiographies, meteorographies, and oceanographies, and we should have glaciology and climatology made up of glaciography and climatography; and ontology or the sequence of organic responses to the changing earth, would be made up of a succession of ontographies.

Schemes of terminology, however, are not often successfully made to order in this fashion; they are slowly evolved without much regard to system, as is seen in the haphazard nomenclature of oceans, seas, gulfs, and bays. Minerography is strange to the point of offense to the ear; we cannot take over biography and physiology from their present uses; we must get along with the terms that we have, and with such new ones as are added from time to time. My only object in suggesting this fanciful scheme is to bring more clearly forward the space- and time-relations that are recognizable in all branches of our subject, as well as in geography and geology. The progress of the last century has certainly brought us now to a stage when these general relationships may be in good part understood, if we give heed to them. We fail to take the best advantage of our progress if we see only the specialized development of our several subsciences.

It has often seemed to me as if petrologists were rather overwhelmed at present with the flood of new facts that modern methods of research have let loose upon them; yet how greatly is the study of both mineralogy and petrography broadened by the addition of the continuous to the momentary consideration of minerals and rocks that the flood has swept before us; for even the rocks have their phases of youth and age. So brief is our life that geomorphologists are even today hardly accustomed to the systematic mobilization of land forms; yet the description of the lands is greatly strengthened when their forms

are seen to be fixed only in the sense that an express train seems to be fixed before the instantaneous wink of a camera's eye. The ontographer may be bewildered when he realizes what the evolutionary struggle for existence means to the individual; and when he thinks how long the world was the scene of relentless strife before pity was born, and how young and impotent pity is still, we may well wonder whether we have yet learned much of omnipotence. Yet how superb is the conception of the procession of life, never halting in its march through the corridors of time.

The addresses of the eight sections into which the department of earth science is divided will so fully consider the special problems with which we are concerned that it has seemed best here to deal only with a few general considerations. I have therefore sought to consider only the prospect from the point of view to which the progress of a hundred years has led us. Vast as is the expanse over which we look, innumerable as are the elements of the view, the chief impression that we gain is one of well-ordered interaction in the continuous progress of events, all of whose momentary geographic phases, with all their parts of earth, air, water, and responding life, are spread upon successive pages in the great volume of geological records.

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